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ORIGINAL ARTICLE

The study on sectional anatomy and imaging of accessory hepatic veins

Yan Zhang · Zhenping Li · Shuwei Liu · Lingzhong Fan · Lei Dong · Lanfen Liu · Bangling Liang

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Abstract To evaluate the distribution and clinical value of accessory hepatic veins (AHVs), we investigated the number and caliber of the AHVs and the angles between the shafts of AHVs and inferior caval vein. We analyzed the anatomical dissections, serial transverse and coronal sections (0.1–0.2 mm) of a frozen liver, and the ultrasonographical and enhanced CT images of healthy patients. We found that: (1) Most of the angles between the AHVs and inferior caval veins on the thin sections (78%) and liver dissections (72%) were acute ($P < 0.01$), while the AHVs with right angles had significantly larger average calibers ($P < 0.05$). However, on the contrary, most of the angles between the AHVs and inferior caval veins were right angles as observed in ultrasonography (89%) and spiral CT images (83%) ($P < 0.01$). The angle parameters appear to be more selective when displaying the AHVs on ultrasonography and spiral CT images. (2) The presentation rates of the AHVs in ultrasonic and spiral CT images were much lower than those of the anatomical dissections ($P < 0.01$). (3) There were no apparent differences in displaying right inferior hepatic veins between ultrasonography and spiral CT ($P > 0.05$). However, the presentation rate of small AHVs was much lower in spiral CT images ($P < 0.05$). (4) The ultrasonographical and spiral CT scans provide effective reference for the diagnosis of Budd-child syndrome, hepatectomy, especially liver hanging maneuver.

Y. Zhang · Z. Li (✉) · S. Liu · L. Fan · B. Liang
Research Center of Sectional and Imaging Anatomy,
Shandong University School of Medicine,
250012 Jinan, Shandong, People's Republic of China
e-mail: zhenping@sdu.edu.cn

L. Dong · L. Liu
Department of Ultrasound,
General Hospital of Jinan Command PLA,
250031 Jinan, Shandong, China

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Introduction

The exploratory studies of development in the accessory hepatic veins (AHVs) can be traced back to 1950s [2]. The nomenclature systems of AHVs used by early investigators are not unified, such as short hepatic veins, small hepatic veins and AHVs, etc. With the advancement of medical image and liver surgical technology, a more precise presentation of AHVs in the orientations are required in the preoperative diagnosis and surgical therapy of hepatic diseases, such as tumors in caudate lobe, cholangiocarcinoma of porta hepatic part and Budd-child syndrome (B-CH) et al. [10]. However, most prior researches only focused on traditional anatomy [4, 11] or medical imaging [5, 7]. In our research, combined with thin sectional anatomy, liver dissection, ultrasonography and spiral CT analysis, we investigated the anatomic features of the AHVs, such as the variations in the angles between the AHVs and inferior caval vein (IVC) and their effects on the venous return, to provide new anatomic and medical imaging information for the diagnosis and surgical treatment of the liver diseases.

Materials and methods

Acquisition of thin sectional anatomic data

Two Chinese cadavers were selected as the specimens. After verified that there were no liver organic lesions in the specimens using the CT and MRI scans, they were embedded with gelatin and frozen under profound hypothermia. To get the transverse data, one of the specimens was serially sectioned from top to bottom with a slice thickness of 0.1 mm. For the coronal data, the other specimen was serially sectioned from anterior to posterior with a slice thickness of 0.2 mm.

Acquisition of liver dissections

After macroscopic observation on the integrality of the IVC and its branches, we choose 26 non-pathologic livers randomly which were fixed by formalin. We applied dissected IVC along the median line of back wall to observe the sources, traces, number and calibers of the AHVs under the anatomy magnifier, as well as the angle between the long shafts of AHVs and IVC (right or acute angle).

Acquisition of ultrasonographic images

The ultrasonographic images were acquired using a GE Vivid7 and Medicine 6000C ultrasound system with the transducer frequency of 3.0–4.0 MHz from 800 healthy subjects (431 males, 369 females) aged from 18 to 65 years (mean = 45.2 $\pm$ 6.8 years). The ultrasound exam was taken of longitudinal section inferior to xiphoid, transection and longitudinal section of right anterior axillary line, transection of middle abdomen and intercostals inclined section surrounding the third porta hepatis. Several ultrasound imaging techniques were applied on each section, including 2D, harmonic, color and power Doppler flow imaging to investigate the anatomy of the AHVs.

Acquisition of spiral CT images

The spiral CT scans were obtained on a SIEMENS Somatom Sensation 64-Slice CT Scanner with the following conditions: 12OKv; 200 mA; pitch: 1; slice: 2 mm; scanner time: 4.8 s. Eighty cases without liver pathological changes were randomly selected for enhanced CT exam to investigate the anatomy of the AHVs and angles between AHVs and IVC. We also choose nine samples for 3D reconstruction and analysis.

Define the angle

We defined the angles between the prolate axis of AHVs and IVC to be acute or right if they are less than or equal to 90°, respectively. In order to measure the angles and calibers of the AHVs in ultrasonographical and spiral CT scans, we drew prolate axis of AHVs and IVC on the serial sections of the frozen liver using software Photoshop. We applied small square ruler to measure the angles and vernier caliper for calibers.

Statistics analysis

We adopted the t test for statistical analysis for our results, as a P value of smaller than 0.05 is considered to be significant.

Results

Thin sectional anatomic data of the liver

There were 12 AHVs in the frozen liver on the transverse and coronal sections. Average number and caliber of the AHVs were 6.0 ± 1.0 and 0.10 ± 0.04 cm, respectively. Also, three AHVs had the right angles with the IVC and the others had the acute angles (Figs. 1, 2, 3). There were two IRHVs and ten caudate lobe veins in the liver sections that usually averaged at about 1 and 5.0 ± 1.0 per person, respectively.

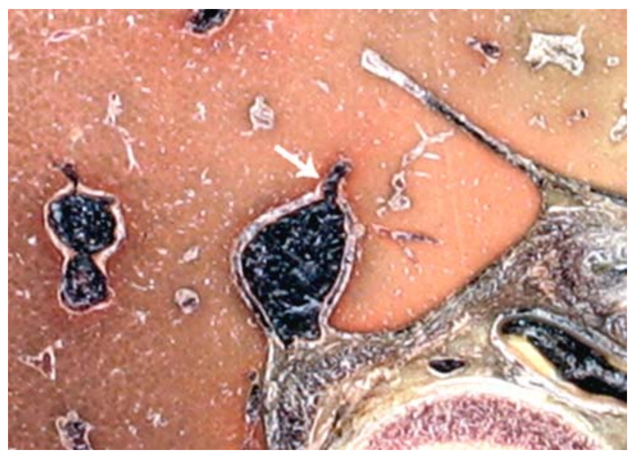

Fig. 1 Transverse section through caudate lobe vein (*white arrow*)

Fig. 2 Transverse section through two AHVs (*white arrows*)

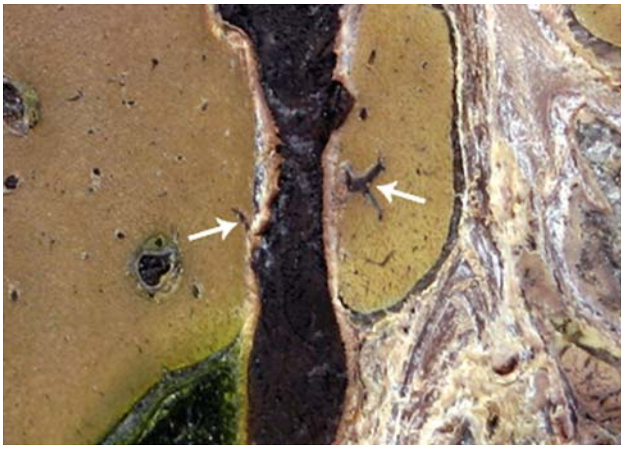

Fig. 3 Coronal section through accessory showing two AHVs (*white arrows*)

Observation of AHVs in the liver dissections

There were a total of 272 AHVs observed in 26 specimen (mean = 10.42 ± 8.1). The average caliber was 0.29 ± 0.22 cm. There were also 195 AHVs that had acute angle with the IVC (mean = 7.51 ± 5.61) with an average caliber of 0.26 ± 0.10 cm. The other 77 AHVs had the right angle with the IVC (mean = 2.91 ± 1.79) with an average caliber of 0.38 ± 0.18 cm (Fig. 4). There were also 18 IRHV in the liver dissection specimens (mean = 0.69 ± 0.25). Table 1 shows the angles between the AHVs and IVC.

Observation of AHVs in ultrasonographic images

There were 568 AHVs observed in 800 samples (mean = 0.79 ± 0.38) with an average caliber of 0.35 ± 0.16 cm. 89% of the angles (505/568) between the IVC and AHVs were right angles (mean = 0.61 ± 0.28) with an average

Fig. 4 The stripped liver specimen showing the AHVs (*black arrow*) and inferior vena cava (*white arrow*)

Table 1 Different included angles between IVC and AHV of liver dissection specimens

	Number (branches)	Mean (branches)	Caliber (cm)	Percentage (%)
Right angle	77	2.91 ± 1.79**	0.38 ± 0.18*	28.0
Acute angle	195	7.51 ± 5.61	0.26 ± 0.10	72.0
Total	272	10.42 ± 8.1	0.29 ± 0.22	100.0

Right angle: acute angle

* $P < 0.05$; ** $P < 0.01$

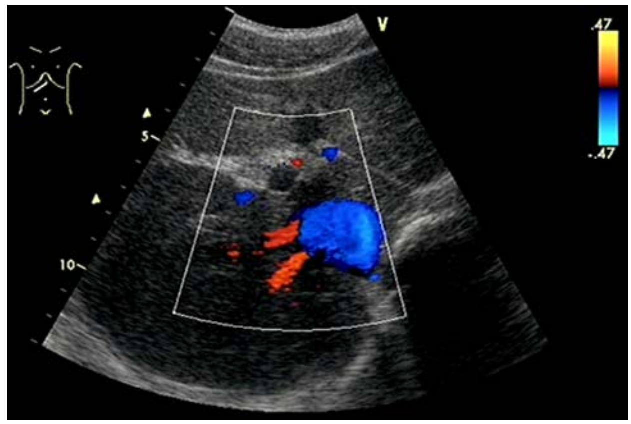

Fig. 5 Color Doppler image showing two AHVs

caliber of 0.36 ± 0.17 cm (Fig. 5). The rest AHVs had acute angles with the IVC (mean = 0.11 ± 0.08) with an average caliber of 0.26 ± 0.12 cm. There were also 230 samples of IRHVs, with calibers ranged from 0.30 to 0.81 cm (mean = 0.40 ± 0.19 cm). Table 2 shows the angles between the AHVs and IVC.

Observation of AHVs in spiral CT images

There were only 29 IRHVs observed in 24 cases of the 80 spiral CT scan images, The caliber sizes ranged from 0.2 to 0.7 cm (mean = 0.34 ± 0.14 cm). Nine samples were chosen for 3D reconstruction and to display the trace of veins in the liver (Fig. 6). Table 3 shows angles between the AHVs and IVC.

Table 2 Different included angles between IVC and AHV on ultrasound images

	Number (branches)	Mean (branches)	Caliber (cm)	Percentage (%)
Right angle	505	0.61 ± 0.28**	0.36 ± 0.17*	89.0
Acute angle	63	0.11 ± 0.08	0.26 ± 0.12	11.0
Total	568	0.80 ± 0.38	0.35 ± 0.16	100.0

Right angle: acute angle

* $P < 0.05$; ** $P < 0.01$

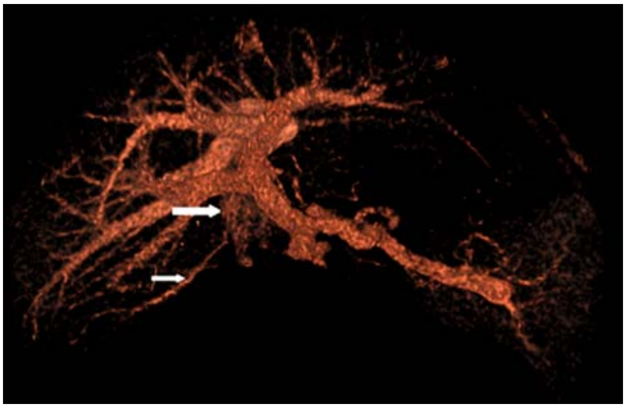

Fig. 6 3D reconstruction of spiral CT showing inferior right hepatic vein

Table 3 Different included angles between IVC and AHV on spiral CT images

	Number (branches)	Mean (branches)	Caliber (cm)	Constituent ratio (%)
Right angle	20	0.21 ± 0.11*	0.35 ± 0.15*	83.0
Acute angle	9	0.10 ± 0.07	0.30 ± 0.10	17.0

Right angle: acute angle

* $P < 0.05$

Most of the angles between the AHVs and IVC shown on thin sections and liver dissections were acute (75 and 72%, $P < 0.01$). And the average caliber sizes of AHVs with right angles were larger ($P < 0.05$). However, most of the AHVs observed in the ultrasonographical and spiral CT images had the right angles with the IVC (89 and 83%, $P < 0.01$). It proves that the ultrasonographical and spiral CT images had selective angle views on displaying the AHVs (Tables 1, 2, 3).

The presentation rate of AHVs in the ultrasonic and spiral CT images was also lower than that of the anatomic images ($P < 0.01$). And there were no obvious differences in displaying the right inferior hepatic veins between the ultrasonography and spiral CT ($P > 0.05$). However, the presentation rate of small AHVs (caudate lobe veins) was lower in the spiral CT images ($P < 0.05$, Table 4).

Discussion

Unlike the left, right and intermediate hepatic veins, the AHVs drain the blood into inferior vena cava directly surrounding the third portal hepatic [2]. In our research, we study the distribution and imaging anatomic features of the AHVs from analyzing the thin sectional anatomy, liver dissections, as well as the ultrasonographical and spiral CT images.

The number of AHVs varies significantly in the large number of normal Chinese population (2–24 branches) and most of the angles between AHVs and IVC were acute ($P < 0.01$). And the average caliber of AHVs with right angles was also larger ($P < 0.05$). However, most of the AHVs observed in the ultrasonographical and spiral CT images were right angles (89%, $P < 0.01$). It may be related to the development process of the AHVs. During the embryonic stage, hepatic venous functions were immature and the pressure was comparatively large. As the hepatic veins mature, subtotals of the blood re-circulate to the IVC through the left, right and intermediate hepatic veins. Reduction in the blood flow in AHVs causes the pressure to decrease. Meanwhile, with the liver augmentation and Couinaud space narrowing, AHVs with long extra-liver segments turn closely and confluent into IVC without changing the size and position, thus resulting acute angles circuitously. AHVs with short extra-liver segments become confluent into IVC with the right angle straightly as the blood flow resistance was low. Lumen of blood vessel shows "compensation enlargement" and large calibers. It shows that the ultrasonographical and spiral CT images have angle selectivity on displaying. AHVs with right angles were more easily to be shown on the images.

Nowadays, the main methods used to observe AHVs include angiography, ultrasonography and CT [5, 7], and the latter two are the common methods in the clinical examination. However, we found that in our research, the presentation rate of AHVs in ultrasonic and spiral CT images are much lower than that of the anatomic images ($P < 0.01$), which indicates that the resolution ratio of ultrasonography and spiral CT is not high enough to show all the AHVs due to the tiny calibers and the scan angle. There were no obvious differences in displaying the RIHVs between the ultrasonographical and spiral CT images. But the presentation rate of small AHVs is lower in spiral CT images. It may be attributed to several factors: (1) the ultrasonic inspection can display any structures at any angles and sections; (2) the ultrasonic inspection display AHVs using color and power Doppler which is clearer and more direct; and (3) for the fixed slice thickness, the smaller veins are more easily missed during a spiral CT scan. After the hepatic arterial

Table 4 Average number of AHVs by different methods

	Thin sections	Liver dissection	Ultrasonography	CT
IRHVs (branches)	1.0 ± 0*	0.69 ± 0.25*	0.30 ± 0.10*	0.32 ± 0.05
Caudate lobe veins (branches)	5.0 ± 1.0**	9.77 ± 4.5**	0.46 ± 0.21**	0
Total (branches)	6.0 ± 1.0**	10.42 ± 8.1**	0.79 ± 0.38*	0.32 ± 0.05

Right angle: acute angle

* $P < 0.05$; ** $P < 0.01$

and portal vein phase, as the contrast concentration degrades during the enhancement scanning, the displayed relative property of structures also degrades.

In comparison with the imageology, the liver dissection specimens and thin sectional anatomy images can show the joined position, number, caliber of AHVs and the angle between the shafts of AHVs and IVC more clearly and accurately, which are critical. The thin sectional anatomy images (0.1–0.2 mm/layer) are able to show the 3D anatomy relationship of the AHVs. Nevertheless, it is still only a study of single specimen. The calibers of AHVs in thin sectional slices are smaller than those of dissection specimens. Besides the individual differences, it may also be related to the change of surroundings pressure after freezing and without blood affuse, which lead to the reduced caliber of the AHVs.

AHVs are small and abundant, but they are very important in the liver surgery. In 2001, Belghiti [1] observed distribution of the AHVs in the anterior inter-space of IVC and proposed liver hanging maneuver (LHM). It was successfully applied in the hepatectomy, liver acquisition and improved parenchymal transection by reducing the operative time and blood loss [3].

Meng et al. [8] applied LHM on the specimen liver, which divided the AHVs into left and right groups with a relative avascular area between them, thus providing an anatomical foundation to the LHM. Our research proves that the ultrasonographical and spiral CT images can show some IRHVs. The ultrasounds exam can even display parts of the caudate lobe veins, thus can be used to guide the surgical operation strategy. Kokudo [6] has reported such a measure that they applied intra-operative ultrasonography during the LHM to avoid damaging the AHVs. The success operation rate was 98.6%. Their display rate was higher than our research. It could be attributed to the high frequency probe they used, which resulted higher resolution ratio.

The ultrasonography and spiral CT also assist in the diagnosis of B-CH syndrome. Prior researches demonstrated that during the ultrasonic inspection, if the AHVs were observed, the person have a much higher possibility of having idiopathic B-CH syndrome [9, 12]. Specifically, ultrasonic inspection can detect the counter-flowing blood in a hepatic vein caused by the collateral blood vessels established or confluent into the inferior vena cava through the caudate lobe vein, which indicates that the proximal part of hepatic veins might be seriously stenotic or obliterating. And most of these researches on the AHVs were about the B-CH syndromes and increased central venous pressure [9, 12]. Due to the limitation of resolution, most researchers considered that AHVs could not be detected in the liver without pathological changes. However, in our research, we found that the ultrasonographical and spiral CT images were able to display part of AHVs, along with part of the small caudate lobe veins. In the routine examination, the occurring of AHVs should combine with case history and biochemistry examination.

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